The effects of nystagmus on reading Japanese language in school-age children

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Abstract

Purpose: To evaluate, through reading speed, the visual performance of Japanese school children with infantaile nystagmus syndrome (INS) in comparison to children with normal vision with respect to the smallest print size used in school texts.

Methods: The Japanese reading chart was used to measure the reading speed of 36 subjects diagnosed with congenital nystagmus. The reading parameters for this group were compared to those of children with normal vision, and the correlation value with visual acuity was determined. For subjects in whom the maximum reading speed declined or the critical print size was large, the type of nystagmus, intensity, presence of a position where the nystagmus was minimal (null zone), and suppression of nystagmus due to convergence were examined.

Results: Maximum reading speed was 60% of the rate for children with normal vision. There was a significantly decline in reading speed even in cases of normal visual acuity ($p = 0.0032$). Critical print size was smaller with improved visual acuity ($r = 0.88$, $p < 0.01$). Reading parameters were found to be reduced in 26 of 36 subjects (72%). Among the 18 subjects whose reading speed and critical print size were both decreased, INS plus congenital cataract and unassociated INS (five subjects for each), INS plus congenital glaucoma (two subjects), INS plus: cone function disorder, macular degeneration, macular hypoplasia, ocular albinism, choroidal coloboma, and retinitis pigmentosa (one subject for each) were observed.

Conclusion: Nystagmus decreases reading efficiency, and requires larger print size for efficient reading. Reading evaluation should be included in testing of school children with INS.

Introduction

Symptoms of congenital nystagmus appear early, sometimes as early as 2 to 3 months after birth. Since oscillopsia is not present, patients with congenital nystagmus usually have good visual acuity. However, fine visual activity can become difficult because of poor pursuit movements and increased nystagmus when the gaze is held steady [1]. Prism spectacles can be used, or surgery for abnormal head posture may be performed, but in many cases no other treatment is given.

There are many electrophysiological studies of eye and head movement in nystagmus [2-4].The

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effect of nystagmus on visual function has traditionally been assessed with visual acuity. Although visual acuity testing is important as an estimation of visual function, it shows only one aspect of visual function, and the effect of nystagmus on learning is not fully understood. Reading, on the other hand, is a foundation of learning for school-age children. Reading ability consists of many factors, including visual experience, visual information processing within the brain, and eye movements. Reading skill can adequately assess aspects of visual function which measurement of visual acuity alone cannot.

The Japanese kana version of the Minnesota Reading Acuity Chart (MNREAD-Jk) (Figure 1) is a reading chart for the assessment of visual function in young children. It is composed of the Japanese phonetic script known as hiragana, with

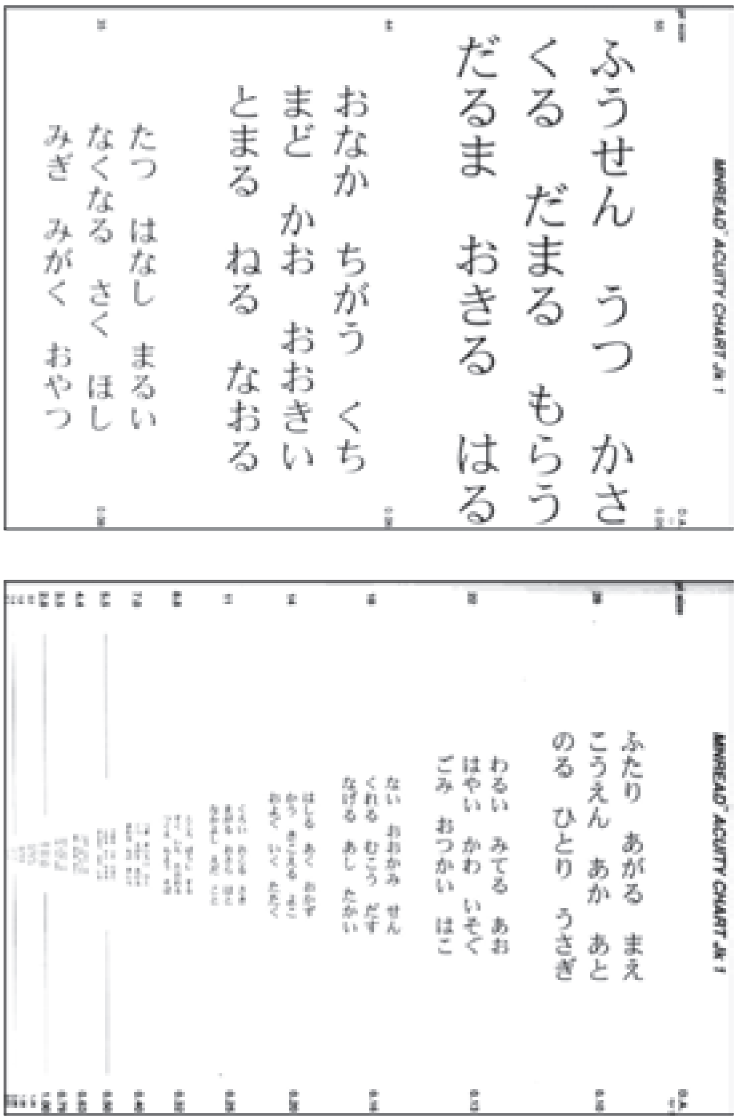

Figure 1. MNREAD-Jk Chart (black characters /white background)
Materials are created by randomly joining words from the 284 words researched to be the most commonly used by small children.

spaces inserted to separate words. Reading is assessed from three parameters: maximum reading speed, critical print size, and reading acuity [5]. An assessment of the child's visual function is made possible by having the child read two-fourletter words common to the vocabulary of young children [5,6]. Understanding the aspects of visual function that are not obtained only through visual acuity testing allows for the objective evaluation of the learning ability of visually impaired children. This type of assessment makes possible the use of various learning supports for individual students, including prescription of visual aids and arrangement of an appropriate learning environment [7,8].

In this study, we sought to quantify the effect of childhood nystagmus on learning through the assessment of reading.

Subjects and methods

Subjects were 36 children, from preschoolers to sixth-graders, that had undergone ophthalmic examinations at Niigata University Medical and Dental Hospital and been diagnosed as having INS. They included seven preschoolers, 15 first-graders, four second-graders, five third-graders, two fourth-graders, two fifth-graders, and one sixth-grade student. Children with evident mental disability were excluded from the study. Informed consent was obtained from all 36 patients.

The primary diseases underlying visual impairment were: unassociated INS (15 subjects), INS plus: congenital cataract (seven subjects), macular hypoplasia (four subjects), ocular albinism and congenital glaucoma (two subjects for each), and other (six subjects).

MNREAD-Jk was used in the reading examination; a practice chart was employed first, and the examination was then performed after the subject sufficiently understood the process. Measurements were taken for each subject with both eyes open and at a distance chosen by the patient (at 30 cm, 15 cm, or 10 cm). Subjects wore their habitual prescription for their refractive condition (either glasses or contact lenses) and measurements were made directly for subjects who did not need correction. Subjects were instructed to read aloud, block by block, from large print size to small print size as quickly and accurately as possible. The reading time required and the number of mistaken characters was recorded. Reading speed = (24 − number of characters misjudged) / (time in seconds for one block) x 60. Three reading parameters: maximum reading speed, critical print size, and reading acuity were calculated from print size, reading time required, and number of misread characters (Figure 2). 'Maximum reading speed' refers to the most rapid reading speed obtained with a suitable print size. 'Critical print size' shows the minimum of a print size that individual can read fastest. 'Reading acuity', a print size that the reader can manage to read, is approximately equal to near visual acuity. Reading acuity = 1.4 − (number of blocks readable x 0.1) + (number of characters misjudged/240) [9]. Print sizes for test distances of 10 or 15 cm were converted into the equivalent sizes for a test distance of 30 cm.

The results for these three reading parameters were compared for each school year with our previous reading speed data [5,6] for children with normal vision. The relationship of visual acuity to critical print size was calculated. With the maximum reading speed for children with normal vision set at 100, each subject within the same age group was categorized into one of the following groups: 1) maximum reading speed only declined, 2) critical print size only declined, 3) maximum reading speed and critical print size both declined, or 4) no decline in reading parameters observed. A visual acuity chart was used to measure visual acuity, it assessed angular vision for children equal to or less than seven years old and evaluated cortical vision for subjects who were more than seven years old.

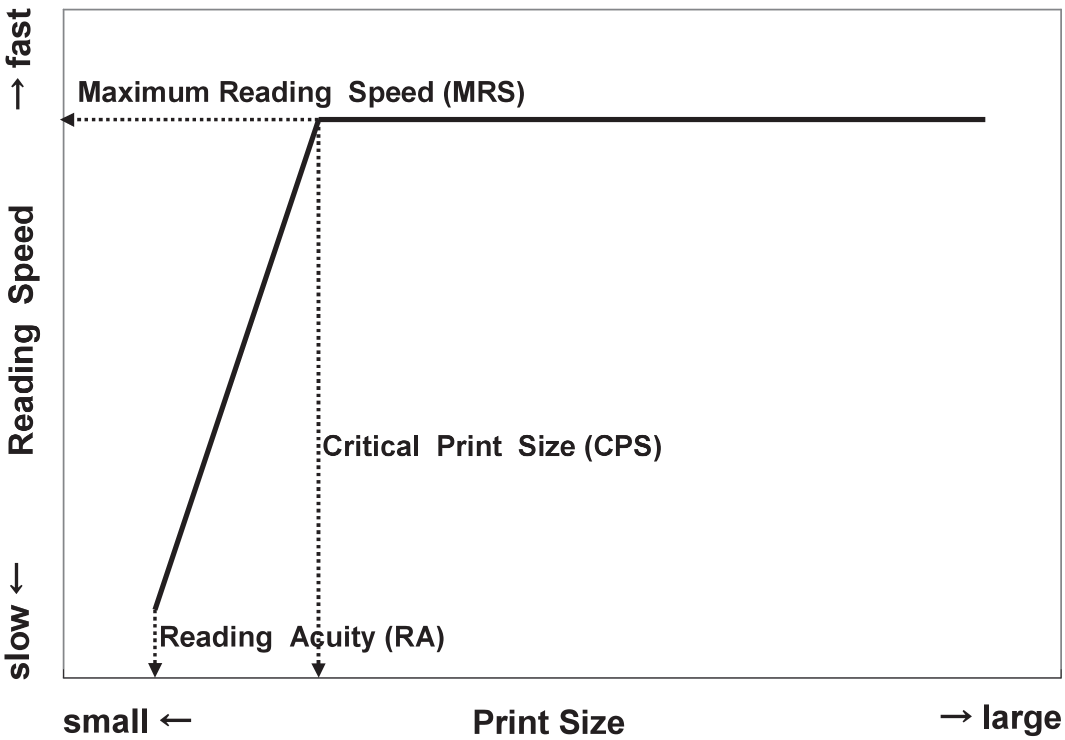

Figure 2. Three reading parameters in nystagumus
Maximum Reading Speed (MRS) = The most rapid reading speed, when reading with a suitable print size.
Critical Print Size (CPS) = A print size which people can read efficiently.
Reading Acuity (RA) = A print size that is readable.

These data were calculated using SPSSII statistical analysis software (SPSS Inc., Chicago, IL), and analyzed by means of Pearson's correlation coefficient test, single regression analysis, and unpaired t-test.

Results

Reading speed examination was possible for all 36 children. It was possible to recognize the reading tendencies and difficulties of school children with nystagmus through observation of the subjects during the collection of the measurements, as an increase in nystagmus intensity, appearance or increase of abnormal head posture, and skipping of lines were observed when the print size became smaller than the critical print size.

Three reading parameters in nystagmus:

The reading parameters were computed for each school year age group. There was great individual variance with regard to maximum reading speed, even among children with normal vision. Maximum reading speed for school children with nystagmus was lower than that of normal vision students for every school-year group. There was little difference across school-age groups in critical print size and reading acuity among children with normal vision. Among school children with nystagmus, however, there was great fluctuation in the values for each school year due to visual function status, and this group had larger values for both critical print size and reading acuity compared to children with normal vision (Table 1).

Table 1. Three reading parameters in nystagumus

	Children with normal vision				Children with congenital nystagmus			
		maximum reading speed (characters/min)	critical print size (logMAR)	reading acuity (logMAR)		maximum reading speed (characters/min)	critical print size (logMAR)	reading acuity (logMAR)
	n	Mean ± sd	Mean ± sd	Mean ± sd	n	Mean ± sd	Mean ± sd	Mean ± sd
Preschooler	40	96.59 ± 44.59	0.20 ± 0.14	0.04 ± 0.11	7	70.74 ± 36.79	0.73 ± 0.52	0.53 ± 0.57
First grade	12	154.49 ± 42.05	0.03 ± 0.10	-0.17 ± 0.07	15	85.83 ± 34.69	0.48 ± 0.34	0.31 ± 0.32
Second grade	12	214.11 ± 29.27	-0.01 ± 0.12	-0.18 ± 0.09	4	133.05 ± 66.53	0.45 ± 0.33	0.29 ± 0.36
Third grade	12	237.40 ± 71.39	0.05 ± 0.12	-0.26 ± 0.29	5	110.47 ± 59.41	0.66 ± 0.38	0.52 ± 0.38
Fourth grade	12	259.78 ± 36.38	-0.01 ± 0.12	-0.16 ± 0.12	2	219.43 ± 110.75	0.25 ± 0.07	0.09 ± 0.16
Fifth grade	12	254.32 ± 51.53	0.02 ± 0.07	-0.21 ± 0.04	2	213.00 ± 13.13	0.35 ± 0.21	0.18 ± 0.12
Sixth grade	12	281.79 ± 57.39	0.01 ± 0.11	-0.18 ± 0.07	1	94.17	1.00	0.99

Relationship between visual acuity, critical print size, and reading efficiency:

As visual acuity (visual acuity of the better eye) improved, critical print size became smaller; r = 0.88 ($p < 0.01$). The smallest print size of Japanese language textbooks in the elementary school is 6.4 point (0.37 logMAR), which corresponds to a visual acuity of 0.14 logMAR (or approximately 0.73 as a decimal visual acuity). The critical print size was larger than 6.4 point (0.37 logMAR) in 23 (64%) of 36 cases. Among the 23 cases for which the decimal visual acuity was less than 0.7, critical print size was larger than 6.4 point (0.37 logMAR) in 20 (87%) of the cases (Figure 3).

With the maximum reading speed average for children with normal vision of the same school year set as 100, the subjects' reading efficiency

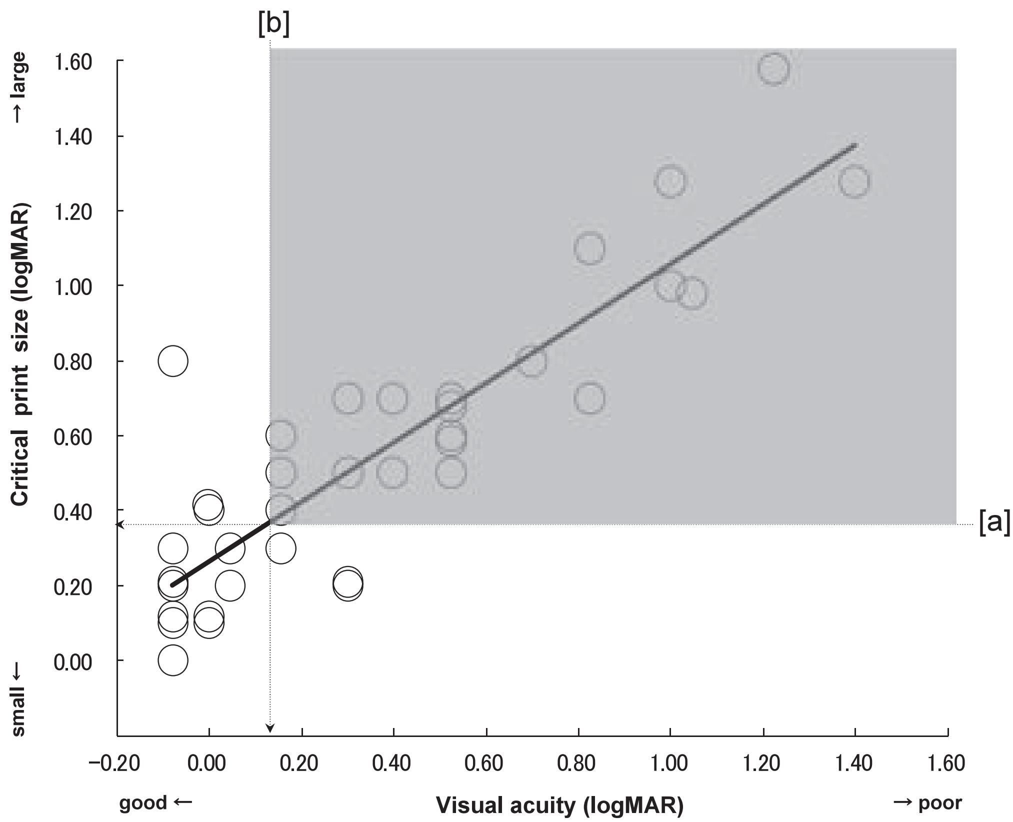

Figure 3. Relationship between visual acuity and critical print size (n=36)
[a] 6.4 point (0.37 logMAR), smallest print size in the elementary school Japanese language textbooks.
[b] 6.4 point corresponds to a visual acuity of 0.14 logMAR ※ (or approximately 0.73 as a decimal visual acuity).
$y = 0.789x+0.2624$, $r = 0.877$ ($p < 0.01$) ※ Conversion to the visual acuity value of the lettersize $=1/10^{\text{logMAR}}$
As visual acuity (visual acuity of the better eye) improved, the critical print size became smaller; r = 0.88 ($p < 0.01$). The smallest print size in the elementary school Japanese language textbooks is 6.4 point (0.37 logMAR), which corresponds to a visual acuity of 0.14 logMAR (or approximately 0.73 as a decimal visual acuity). The critical print size was larger than 6.4 point (0.37 logMAR) in 23 (64%) of all 36 cases. Among the 23 cases for which the decimal visual acuity was less than 0.7, the critical print size was larger than 6.4 point (0.37 logMAR) in 20 (87%) of the cases.

average was 60.29 ± 28.74%. A correlation ($r = 0.61$, $p < 0.01$) was found between visual acuity and reading efficiency. Among the 23 cases where the decimal visual acuity value was less than 0.7, reading efficiency was lower than that of children with normal vision (more than one standard deviation below the average maximum reading speed of children with normal vision of the same school year) in 18 cases (78%) (Figure 4). The mean maximum reading speed for the 11 children with acuity in the normal range (a decimal acuity of 1.0 or 1.2), was 108.82 ± 48.16 characters/minute, a significant decline in comparison to children with normal vision ($p = 0.0032$) (Table 2).

Classification of subjects and group profiles:

The maximum reading speed was more than one standard deviation below the average for children with normal vision of the same school

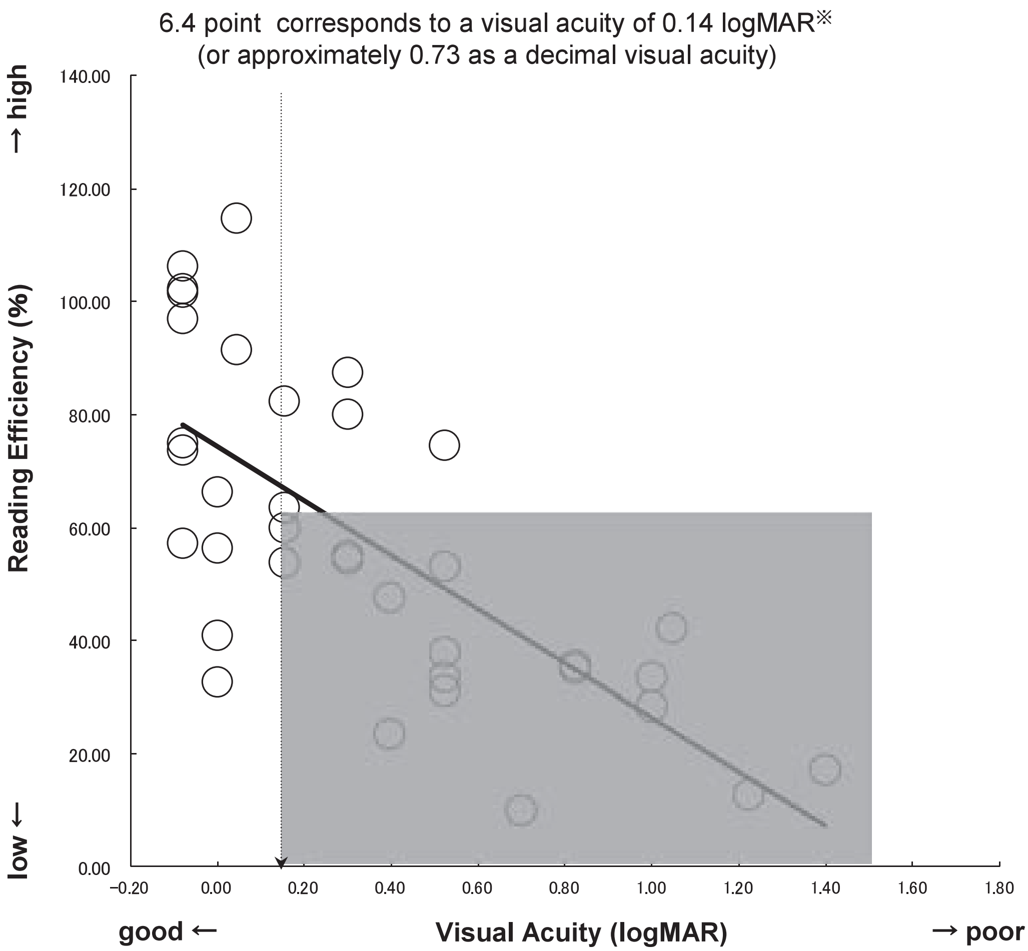

Figure 4. Relationship between visual acuity and reading efficiency (n = 36)
$y = -49.08x+74.475$, $r = 0.605$ ($p < 0.01$) ※ Conversion to the visual acuity value of the letter size=$1/10^{logMAR}$
With the maximum reading speed average for children with normal vision of the same school-year set as 100. A correlation of $r = 0.61$ ($p < 0.01$) was found between visual acuity and reading efficiency. Among the 23 cases in which the decimal visual acuity value was less than 0.7, the reading efficiency was lower than that of normal vision children (more than one standard deviation below the average maximum reading speed for normal vision children of the same year in school) in 18 (78%) cases.

year in three cases (8%). The critical print size was larger than 6.4 point (0.37 logMAR) in five cases (14%). In 18 cases (50%) there was a decline in maximum reading speed and a critical print size larger than 6.4 point. A decline in reading parameters was observed in 72% of the total number of cases. Ten cases (28%) were found to have no decline in reading parameters. Reading parameters did not often decline separately; maximum reading speed and critical print size declined together in 18 of the 26 cases (69%) (Figure 5).

Subjects were categorized into four groups based on maximum reading speed and critical

Table 2. Maximum reading speed for the children with visual acuity in the normal range ※1

	Children with normal vision n = 64 (preschooler n = 40, first grade n = 12, second grade n = 12)	Children with congenital nystagmus n = 11 (preschooler n =2, first grade n = 8, second grade n = 1)
Average	149.38 ※2	108.82
Standard deviation	31.58	48.16
Unpaired *t*-test	p = 0.0032	

※1 Decimal visual visual acuity 1.0 ～ 1.2 (0.00 ～ -0.08 logMAR)
※2 Average in preschooler, first grade and second grade

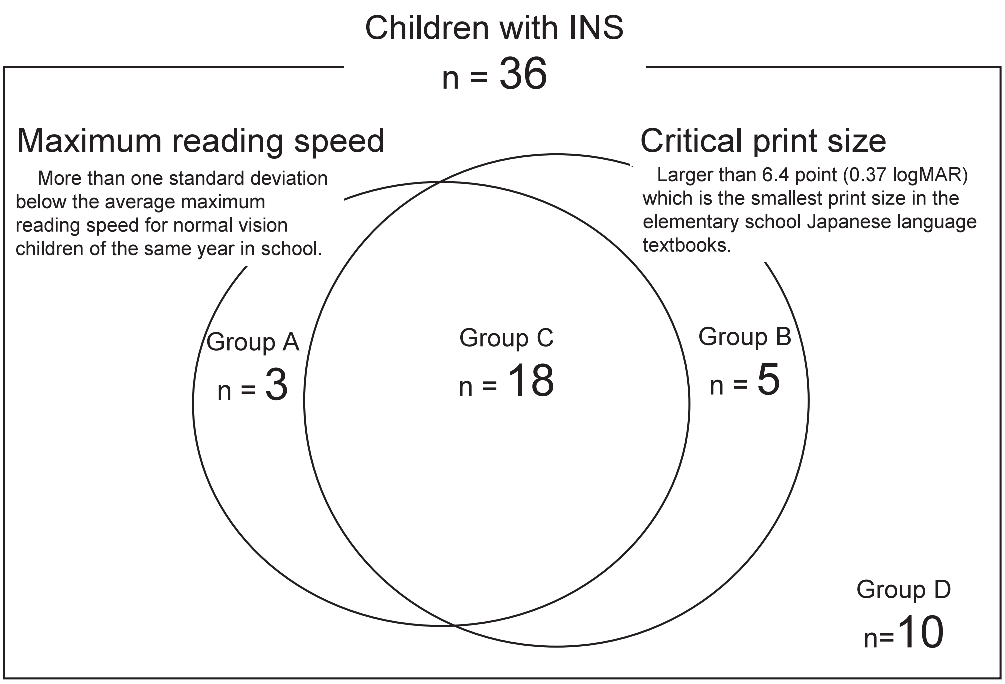

Figure 5. Classification of maximum reading speed and critical print size (n = 36)
Group A consists of cases in which only maximum reading speed declined.
Group B consists of cases in which only critical print size was large.
Group C consists of cases in which maximum reading speed declined and critical print size was large.
Group D consists of cases that were judged to have no problems with reading performance.

Table 3. Classification of subjects and group profiles

Cases		Primary disease of visual impairment	School year at the time of the examination	Visual acuity of the better eye (decimal)
Group A	1	unassociated INS	first grade	1.0
	2	INS plus accommodative esotropia	first grade	1.2
	3	INS plus macular hypoplasia	fourth grade	0.5
Group B	1	INS plus macular hypoplasia	preschooler	0.2
	2	unassociated INS	preschooler	0.7
	3	unassociated INS	preschooler	1.2
	4	INS plus macular hypoplasia	third grade	0.3
	5	INS plus ocular albinism	fifth grade	0.5
Group C	1	INS plus postoperative cataract (both eyes)	preschooler	0.2
	2	INS plus cone functional disorder	preschooler	0.1
	3	unassociated INS	first grade	1.0
	4	INS plus congenital glaucoma	first grade	0.1
	5	unassociated INS	first grade	0.7
	6	INS plus macular degeneration	first grade	1.0
	7	INS plus ocular albinism	first grade	0.3
	8	INS plus postoperative cataract (both eyes)	first grade	0.3
	9	INS plus postoperative cataract (both eyes)	first grade	0.3
	10	INS plus postoperative cataract (both eyes)	first grade	0.3
	11	INS plus cataract (both eyes)	first grade	0.1
	12	INS plus choroidal coloboma	second grade	0.4
	13	INS plus congenital glaucoma	second grade	0.2
	14	unassociated INS	second grade	0.7
	15	unassociated INS	third grade	0.5
	16	unassociated INS	third grade	0.4
	17	INS plus retinitis pigmentosa	third grade	0.04
	18	INS plus macular hypoplasia	sixth grade	0.1
Group D	1	INS plus postoperative cataract(both eyes)	preschooler	1.2
	2	unassociated INS	preschooler	1.0
	3	unassociated INS	first grade	0.9
	4	unassociated INS	first grade	1.2
	5	INS plus postoperative cataract (right eye)	first grade	1.2
	6	unassociated INS	first grade	1.2
	7	unassociated INS	second grade	1.2
	8	unassociated INS	third grade	0.7
	9	unassociated INS	fourth grade	0.9
	10	INS plus retinopathy of prematurity	fifth grade	0.5

Group A: Maximum reading speed was lower more than one standard deviation below the average maximum reading speed for normal vision children of the same year in school.

Group B: Critical print size was larger than 6.4 point.

Group C: Maximum reading speed was lower more than one standard deviation below the average maximum reading speed for normal vision children of the same year in school, and critical print size was larger than 6.4 point.

Group D: Maximum reading speed was faster more than one standard deviation below the average maximum reading speed for normal vision children of the same year in school, and critical print size was smaller than 6.4 point.

print size (Table 3):

Group A (three cases) consisted of cases in which there was a decline in maximum reading speed only. Critical print size was smaller than 6.4 point (0.37 logMAR). Even with a suitable print size, there was a decline in reading speed compared to children with normal vision.

Group B (five cases) consisted of cases in which only the critical print size was large, though a maximum reading speed was obtained approximately equal to children with normal vision of the same school year, it was only possible for these subjects to read efficiently with a print size larger than 6.4 point (0.37 logMAR).

Group C (18 cases) consisted of cases in which a maximum reading speed similar to that of children with normal vision of the same school year could not be obtained, even with a print size larger than 6.4 point (0.37 logMAR). The critical print size was larger than 6.4 point (0.37 logMAR) in 5 of the 6 postoperative cataract cases, and a decline in maximum reading speed was observed.

Group D (10 cases) consisted of cases that were judged to have no problems with reading performance. In these cases a maximum reading speed similar to children with normal vision of the same school year was obtained with a critical print size smaller than 6.4 point.

Discussion

In this study, decline in reading efficiency was observed in 21 of the 36 subjects with nystagmus. There were many cases of decreased reading efficiency even among subjects with good visual acuity. Visual acuity is greatly influenced by whether or not there is a fixation point within 0.5 degrees of the central fovea and whether there are few fixation changes; however, reading is influenced by eye movement and visual information processing within the brain.

There has been quite a bit of clinical psychology research into eye movement during reading. In most such studies, usually conducted in English-speaking countries, horizontally-formatted reading charts were used [10-12]. Japanese is traditionally written vertically, but recently, there is a trend to write sentences horizontally. Nevertheless, both the national language textbooks used in the early elementary grades and newspapers are written vertically. Due to this, a vertically-written MNREAD-Jk was used in our study. Many studies of nystagmus evaluate horizontal eye movement; our study is unique in that we are evaluating eye movement in vertical direction. Igawa et al. compared eye-movement during reading sentences written vertically and horizontally and reported that eye movement speed becomes slower when reading vertically-written sentences because fixation time increases and visual line movement velocity decreases [13], and eye movement in the horizontal direction is faster than seen in the vertical direction.

Reading involves not only saccades following sentences and new lines, but it is a repeated process of saccades that quickly move the fixation point to different areas to acquire textual information and fixations to hold the gaze steadily on a point in the visual field. Three to four characters are read at a time and then attention is shifted to the next group of characters. Reversals of direction, called regression, also occur. These eye movements during reading play a part in reading speed. Fixations become longer with smaller character size and more difficult material [14,15]. Saccadic speed increases, saccadic latency is reduced [16,17], and fixation time declines with age in normally-sighted children. With visually-impaired children, this trend may differ. Foveation periods are intervals in the nystagmus waveform when the eye velocity is relatively slow and the target is imaged on or near the fovea; the eye is moving slowly enough for useful vision to be achieved [18]. Furthermore, infants with congenital nystagmus tend to have increased foveation periods [19].

Woo et al. reported that reading efficiency improved in sentences of larger print size, and the reading performance of people with nystagmus was promoted by making print size larger [20]. The critical print size in the MNREAD assessment is that print size the subject can read most efficiently. In this study, the critical print size was large in nystagmus, just as Woo et al. reported. The critical print size in the MNREAD assessment is also one level above the size in which there is a precipitous decline in reading speed, and it is a principal reading parameter. Critical print size was strongly correlated with visual acuity, as the more visual acuity worsened, the more critical print size increased. The critical print size is determined by visual acuity. The smallest print size in elementary school Japanese language textbooks is 6.4 point (0.37 logMAR). In the 23 cases where critical print size was larger than 6.4 point (0.37 logMAR), an efficient reading rate was not possible unless the textbook characters were magnified. A critical print size of 6.4 point corresponds to a decimal visual acuity value of 0.73; if the acuity value was greater than 0.7, the individual was judged to be able to efficiently read textbook characters with a minimum size of 6.4 point. When the critical print size is large, educational assistance such as enlarged copies or magnifiers with visual aids will, at times, be necessary. Recently, enlarged text character textbooks for visually-impaired children have been provided free from the Ministry of Education, Culture, Sports, Science, and Technology in Japan.By directly assessing reading, the critical print size can be used as a reference when searching for an appropriate character size for a child's reading.

Harold et al. assessed the relationships between visual acuity and the amplitude, frequency, and duration of foveation periods in congenital nystagmus [21]. No significant correlation existed between visual acuity and any measured eye movement parameter [21]. In our study, reading performance was affected by visual acuity. Particularly, there was a high incidence of a decline in reading performance among cases where nystagmus was present and visual acuity was less than 0.7. There was also a significant decline in maximum reading rate, relative to children of normal vision, even in cases where the visual acuity was good. It has been reported that there are not the relations between reading speed and visual acuity [12,22]. However, these are studies for adults.It is well known that reading speed varies according to a course of the learning [23]. Learning progress condition and the reading speed influence each other. On reading, children of low visual acuity may lack interest. The Children withINS who had poor visual acuity might have a short fixation time. For reasons of them, it is supposed that visual acuityand reading efficiency showed spurious correlation in it.

Visual performance of children with congenital nystagmus cannot be evaluated only by visual acuity testing. When nystagmus is present, it is recommended that reading be assessed even in cases where visual acuity is good.

In many cases, a visually-impaired child will deal with small print size by bringing it nearer to increase retinal image size; in cases where nystagmus is present, we cannot expect this to improve reading efficiency except for cases where there is suppression of nystagmus due to convergence. In the aphakic eye of postoperative cataract patients, where there is no accommodative ability, there is no anticipated retinal image enlargement due to proximity, but reading performance may be improved with near refractive correction.

Average reading efficiency of school children with nystagmus was 60% of the performance of children with normal vision. Even with the print size set to a suitable level, in many cases the efficiency of letter data processing was slowed. It is essential to provide coaching and training suited to the individual child, as well as providing information to educational institutions, so that school children with nystagmus can make progress in learning together with students with normal vision.

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